REMARKS

Claims 1-10 are pending in the present application. Claims 1, 3 and 6 are independent. Reconsideration of this application, in view of the following remarks, is respectfully requested.

Rejection Under 35 U.S.C. § 103

Claims 1 and 2 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Rankin et al, U.S. Patent No. 5,489,099 in view of Edelson et al., U.S. Application Publication No. 2002/0054211 A1. Claims 3 and 4-8 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Rankin et al. in view of Yokota et al., U.S. Patent No. 5,905,530. Claims 9 and 10 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Rankin et al. in view of Edelson et al. and further in view of Yokota et al. These rejections are respectfully traversed.

At the outset, as the Examiner will note, attached hereto is a verified translation of Japanese Application No. 2000-339896, which was filed on November 8, 2000. In view of this, the foreign priority of the present application has been perfected to November 8, 2000. Referring to the Edelson et al. reference relied on by the Examiner, this reference was filed on November 5, 2001, which is after the perfected filing date of the present application of November 8, 2000. In view of this, the Edelson et al. reference is only available as a reference against the present invention with regard to the subject matter that is present in

U.S. Provisional Application No. 60/245,710 (hereinafter "the '710 Application), filed on November 6, 2000. Since the Examiner has not explained that the '710 Application includes the same subject matter as the Edelson et al. Published Application, Applicants respectfully submit that the Examiner has not established a *prima facie* case of obviousness.

For the convenience of the Examiner, attached hereto is a copy of the '710 Application. Applicants submit that the '710 Application does not include the same subject matter as the '710 Application and therefore, the Examiner's rejection is improper without an explanation with regard to where in the '710 Application there is sufficient teaching to modify the Rankin et al. reference to arrive at the presently claimed invention. Since the Examiner has not provided such an explanation, Applicants reiterate that the Examiner has not established a *prima facie* case of obviousness.

It should also be noted that the '710 Application has a filing date of November 6, 2000, which is only two days prior to the filing date of the present application of November 8, 2000. If the Examiner does persist in the rejection in view of the Edelson et al. reference, Applicants reserve the right to file a Declaration to antedate the Provisional Application filing date of the Edelson et al. reference.

In any event, Applicants present the following arguments against the Examiner's rejection, taking into consideration the disclosure in the '710 Application. With regard to independent claim 1, this claim is directed to a ball motion measuring apparatus and recites

a combination of elements including "a calculating section for carrying out a magnifying process of only a portion of an original image including a ball image, thereby calculating magnified image data" and "a display section for displaying a magnified image based on the magnified image data wherein the magnified image data is used to calculate ball motion." Applicants respectfully submit that the combination of Rankin et al. and Edelson et al. fails to render obvious the present invention as recited in independent claim 1.

In particular, referring to Rankin et al., this reference is directed to an apparatus and method for tracking the flight of a golf ball. Referring to column 3, lines 55-62 of Rankin et al., it is disclosed that an image controller 27 is used to focus the camera lens on the golf ball and control the zoom or magnification of the camera lens in order to maintain a consistent ball image size within a video frame. In view of this, there is no magnification process of an original image as recited in independent claim 1 of the present invention. In Rankin et al., there is only original image data. The focusing and zooming of the camera lens do not result in magnified image data, but result in original image data that is focused and closer to the ball than if the zoom feature was not included. As recognized by the Examiner, since the Rankin et al. reference only discloses original image data, the Rankin et al. reference fails to disclose the use of magnified image data to calculate ball motion as recited in independent claim 1 of the present invention. However, the Examiner relies on the Edelson et al. reference in order to modify Rankin et al. to arrive at the presently

claimed invention. Applicants respectfully submit that the Examiner's modification would not arrive at the presently claimed invention.

In the Examiner's Office Action, the Examiner asserts that Edelson et al. discloses a "magnifying process for calculating motion" (see page 2, paragraph 3, lines 7-9 of the Examiner's Office Action). Although the Edelson et al. reference ('710 Application) may disclose magnification of an image, Edelson et al. does not disclose calculating any motion with the magnified portion of the image. Referring to the '710 Application, this document describes a surveillance device. At page 3, paragraph 2 of this document, it is stated "[w]ith motion identified, moving objects can be highlighted, <u>enlarged,</u> tracked and alarmed." (emphasis added). In addition, on page 7, lines 6-8, it is stated "**Binocular Effect** – An area surrounding the object can be defined to be magnified. This area will have a zoom effect, magnifying the area by 2x or 4x while leaving the area outside the area unchanged." In view of this, the '710 Application appears to disclose "magnification" of image data. However, there is no description in the '710 Application of using the magnified image data to calculate any motion of the magnified image, and there is certainly no description in the '710 Application of calculating ball motion as recited in independent claim 1 of the present invention. In view of this, Applicants submit that the Edelsen et al. reference is insufficient to modify Rankin et al. to arrive at the present invention as recited in claim 1. Specifically, any modification of Rankin et al. in view of Edelson et al. would only result in the image data being magnified. There is insufficient teaching in Edelson et

al. to modify Rankin et al. to magnify the image data **and** use the magnified image data to calculate ball motion. In view of this, the Examiner's rejection of claim 1 in view of the Edelson et al. reference is improper and should be withdrawn.

With regard to dependent claims 2, 9 and 10, Applicants respectfully submit that these claims are allowable due to their dependence on independent claim 1, as well as due to the additional recitations in these claims.

With regard to independent claims 3 and 6, the Examiner recognizes that the Rankin et al. reference fails to disclose "a calculating section for correcting a coordinate error" as recited in independent claims 3 and 6 of the present invention. However, the Examiner relies on the Yokota et al. reference in order to modify Rankin et al. to arrive at the presently claimed invention. Applicants submit that the Yokota et al. reference fails to make up for the deficiencies of Rankin et al.

It should be noted that independent claims 3 and 6 recite "a calculating section for correcting a coordinate error of only a ball image in the original image." In addition, independent claims 3 and 6 recite "said correction data being used to calculate true coordinates of the ball image." As recognized by the Examiner, the Rankin et al. reference fails to disclose calculating any coordinate error and fails to disclose using correction data to calculate true coordinates of the ball image. In view of this, the only element of independent claims 3 and 6 that Rankin et al. discloses is a CCD camera and calculating motion of a ball from the ball image. Applicants respectfully submit that the Yokota et al.

reference certainly fails to make up for all of the deficiencies of Rankin et al. There is absolutely no suggestion in the Yokota et al. reference to calculate a coordinate error <u>and</u> use correction data to calculate ball motion as recited in independent claim 1.

Referring to Yokota et al., this reference discloses an image pickup apparatus that corrects distortion of an <u>image</u> due to an objective lens, not an <u>object</u> in an image. In addition, Yokota et al. fails to disclose calculating anything with regard to the corrected image. In view of this, Applicants submit that there is insufficient suggestion in Yokota et al. to modify Rankin et al. to both calculate a coordinate error to obtain correction data <u>and</u> use the correction data to calculate true coordinates of the ball image as recited in independent claims 3 and 6 of the present invention.

The Yokota et al. reference is not directed to a camera, which is used for measuring any motion, in particular ball motion as recited in independent claims 3 and 6 of the present invention. In view of this, there is no suggestion in the Yokota et al. reference to use corrected data for calculating motion of an object. Therefore, there is insufficient suggestion to modify the Rankin et al. CCD camera to both calculate a coordinate error to obtain correction data <u>of only a ball image</u> <u>and</u> use the correction data to calculate <u>true coordinates</u> of the ball image as recited in independent claims 3 and 6 of the present invention.

With specific regard to independent claim 6, the Examiner asserts that this claim is similar to claim 3 and therefore is also rejected in view of the Rankin et al. and Yokota et al.

references. Specifically, the Examiner asserts that the shift of a direction of the object image would be included in the process of correcting the object image distortion. However, independent claim 6 recites that the calculating section corrects a coordinate error of only a ball image in the original image "made by a shift of a direction of the ball image from a direction of an optical axis of the CCD camera." This aspect of the present invention has nothing to do with the distortion caused by the lens of the CCD camera. The coordinate error caused by "a shift of a direction of the ball image from the direction of the optical axis of the CCD camera" is due to the ball 1 being shifted from the reference plane (see the reference plane s in Figure 5 of the present invention). Referring to page 9, second full paragraph of the present invention, this aspect of the present invention is described. Specifically, if the ball 1 is shifted from the reference plane s due to a shot that is not straight, the z coordinate of the ball is not zero. Therefore, the coordinate error calculated in claim 6 is due to the ball being closer to or further away from the reference plane. In view of this, in addition to the above deficiencies of Yokota et al., Applicants submit that this reference also fails to disclose calculating a coordinate error due to a shift of a direction of the ball image from a direction of the optical axis of the CCD camera as recited in claim 6.

With regard to dependent claims 4, 5, 7 an 8, Applicants respectfully submit that these claims are allowable due to their respective dependence on independent claims 3 and 6, as well as due to the additional recitations in these claims.

In view of the above amendments and remarks, Applicants respectfully submit that claims 1-10 clearly define the present invention over the references relied on by the Examiner. Accordingly, reconsideration and withdrawal of the Examiner's rejections under 35 U.S.C. § 103 are respectfully requested.

CONCLUSION

All the stated grounds of rejection have been properly traversed and/or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently pending rejections and that they be withdrawn.

It is believed that a full and complete response has been made to the Office Action, and that as such, the Examiner is respectfully requested to send the application to Issue.

In the event there are any matters remaining in this application, the Examiner is invited to contact Paul C. Lewis, Registration No. 43,368 at (703) 205-8000 in the Washington, D.C. area.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

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PATENT
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IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant:	Akio YAMAMOTO et al.	Conf.:	4907
Appl. No.:	09/986,114	Group:	2613
Filed:	November 7, 2001	Examiner:	SENFI, Behrooz M
For:	BALL MOTION MEASURING APPARATUS		

VERIFICATION OF TRANSLATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Keiko Kimoyama, a citizen of Japan residing at c/o Oka & Partners, 8th Fl., Sakae Bldg., 1-1 Motomachidori 6-chome, Chuo-ku, Kobe, Japan hereby declare:

That I am knowledgeable in the English language and in the Japanese language;

That I can translate from Japanese into English;

That the English translation attached hereto is a true and complete translation of the Japanese Priority Document No. 2000-339896 dated November 8, 2000;

That all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: January 12, 2005 Signature: K. Kimoyama

JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application: November 8, 2000
Application Number: 2000-339896
Applicant(s): SUMITOMO RUBBER INDUSTRIES, LTD.

August 17, 2001
Commissioner, Japan Patent Office
Certification No. 2001-3073489

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【Attorney Docket Number】 P-0185
【Filed on】 November 8, 2000
【Addressed to】 Commissioner of the Japanese Patent Office
【International Patent Classification】 G01B 11/00
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【Number of claims】 6
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  【Name or Company name】 Kengo OKA
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  【Prepayment Code】 091444
  【Costs to be paid】 21000 yen
【List of the annexed papers】
  【Name of the annexed】 Specification 1 copy
  【Name of the annexed】 Drawings 1 copy
  【Name of the annexed】 Abstract 1 copy
  【Authorized under General Power Number】 0001533
【Request for proof】 Needed

【Name of the Document】 Specification

【Title of the Invention】 Ball Motion Measuring Apparatus

【What is claimed is】

【Claim 1】

A ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data;

a calculating section for carrying out a magnifying process over a part including a ball image in an original image, thereby calculating magnified image data; and

a display section for displaying a magnified image based on the magnified image data.

【Claim 2】

A ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data; and

a calculating section for correcting a coordinate error made by a distortion of an original image which is caused by a lens of the CCD camera, thereby calculating correction data.

【Claim 3】

The ball motion measuring apparatus according to claim 2, wherein the coordinate error is corrected based on a correction ratio determined by a distance from a center of the original image.

【Claim 4】

A ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data; and

a calculating section for correcting a coordinate error made by a distortion of an original image which is caused by a lens of the CCD camera, thereby calculating correction data.

【Claim 5】

The ball motion measuring apparatus according to claim 4, wherein the correction of the coordinate error serves to convert data obtained from an original image into data obtained by photographing a front part of the ball at infinity.

【Claim 6】

The ball motion measuring apparatus in any one of claims 1 to 5, wherein the CCD camera has a horizontal view angle of 10 degrees or more.

【Detailed description of the invention】

【0001】

【Field of the invention】

The present invention relates to a motion measuring apparatus for a ball such as a golf ball or a tennis ball. More particularly, the present invention relates to an apparatus for measuring the motion of a ball by utilizing image data obtained by a CCD camera.

【0002】

【Description of the related art】

When a golf ball is hit with a golf club, it flies with a so-called backspin. The backspin is a rotation setting a horizontal direction orthogonal to a hitting direction (which will be hereinafter referred to as a "z direction") to be an axis. A lift acts on the golf ball through the backspin, thereby increasing a flight distance of the golf ball. In some cases, the golf ball flies with a so-called sidespin. The sidespin is a rotation setting a vertical direction (which will be hereinafter referred to as a "y direction") to be an axis. The golf ball turns left (a draw ball for a right-handed golf player) or turns right (a fade ball for the right-handed golf player) due to the sidespin. Furthermore, the golf ball sometimes flies with a rotation setting a horizontal direction identical to the hitting direction (which will be hereinafter referred to as an "x direction") to be an axis.

【0003】

A direction of the spin and a rotating speed greatly influence the subsequent trajectory of the golf ball. Similarly, the flight direction and flight speed of the golf ball greatly influence the subsequent trajectory. The measurement of the spin, the flight direction and the flight speed is effective for diagnosing the swing form of a golf player.

Moreover, the measurement is also effective for the evaluation of a golf ball and a golf club. In a stage in which the golf ball and the golf club are developed, the measurement is inevitable.

[0004]

Japanese Unexamined Patent Publication No. Hei 3-210282 (1991/210282) has disclosed an apparatus for photographing a flying sphere twice by means of a camera and measuring the flight speed of the sphere based on two images thus obtained. In the apparatus, the moving distance of the sphere is obtained from the two images and is divided by a photographing time interval so that the flight speed is calculated.

[0005]

Japanese Patent No. 2810320 has disclosed a measuring method for photographing a flying golf ball twice at a predetermined time interval and calculating a spin rate from two images thus obtained. In the measuring method, a recognition mark put on the surface of the golf ball is read from first and second images and a rotating angle from the first image to the second image is obtained based thereon. The spin rate is calculated by the rotating angle and the photographing time interval.

[0006]

Japanese Unexamined Patent Publication No. Hei 10-186474 (1998/186474) has disclosed a measuring method for photographing a flying sphere by means of two cameras in a shifted timing and calculating a spin rate, a flight speed and a flight direction from two images thus obtained.

[0007]

[Problem to be solved by the invention]

In the case in which the flying golf ball is to be photographed by means of a camera, it is necessary to predict the position of the golf ball when a predetermined time passes after hitting and to determine the position of the camera such that the same position is included within a visual field. The head speed of a golf club is greatly varied depending on a golf

player. Moreover, there are various golf clubs from a driver (W1) to a wedge. A head speed and a launch angle are greatly varied depending on the type of the golf club. Accordingly, the position of the golf ball after a predetermined time passes since hitting is considerably changed for each golf player or each used club. Therefore, it is not easy to predict the position of the golf ball after the predetermined time passes since the hitting. Even if the prediction can be carried out, a work for often changing the position of the camera is complicated.

[0008]

By using a camera having a wide-angle lens (that is, a camera having a great angle of view), the visual field range is increased. Also in the case in which a hitting golf player take turns or a golf club to be used is changed, therefore, it is not necessary to often change the position of the camera.

[0009]

However, a ball in an image obtained by the camera having a great angle of view is reduced. Accordingly, in the case in which an operator specifies a predetermined point of the ball image through an input pen or the like to measure a spin rate, there is a problem in that precision in the pointing is deteriorated. Moreover, the image obtained by the camera having a great angle of view has a considerable distortion in a peripheral portion (a portion having a great distance from the center of the image). Therefore, true coordinates are considerably shifted from apparent coordinates on the image so that the precision in a measured value becomes insufficient in some cases. In many cases, furthermore, the ball is not positioned on the center of the image in the photographing using the camera having a great angle of view. For this reason, the front part of the ball cannot be photographed but the ball is photographed in an oblique direction. Thus, the true coordinates are considerably shifted from apparent coordinates on the image so that precision in the measured value becomes insufficient.

【0010】

In consideration of such problems, it is an object of the present invention to provide an apparatus for measuring the motion of a ball with high precision.

【0011】

【Means for solving problem】

In order to achieve the object, the present invention provides a ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data;

a calculating section for carrying out a magnifying process over a part including a ball image in an original image, thereby calculating magnified image data; and

a display section for displaying a magnified image based on the magnified image data.

【0012】

In the ball motion measuring apparatus, only a portion including the ball image in the original image is magnified and displayed on the display section. Accordingly, in the case in which an operator is to specify the predetermined point of the ball image, precision in pointing is high. Consequently, a measured value (such as a spin rate, a flight speed or a flight direction) can be obtained with high precision. This process will be hereinafter referred to as a "magnifying process".

【0013】

In order to achieve the object, moreover, another invention provides a ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data; and

a calculating section for correcting a coordinate error made by a distortion of an original image which is caused by a lens of the CCD camera, thereby calculating correction data.

【0014】

In the ball motion measuring apparatus, the shift of apparent coordinates on the original image from true

coordinates is corrected. More specifically, correction data are obtained by modifying the distortion in the peripheral portion of the original image which is caused by the lens. Accordingly, the ball motion can be measured with high precision. The correction will be hereinafter referred to as "distortion correction".

[0015]

It is preferable that the coordinate error should be corrected based on a correction ratio determined by a distance from a center of the original image. Consequently, the precision in measurement can further be enhanced.

[0016]

In order to achieve the object, moreover, a further invention provides a ball motion measuring apparatus comprising:

a CCD camera for photographing a flying ball to obtain original image data; and

a calculating section for correcting a coordinate error made by a shift of a direction of a ball image from a direction of an optical axis of the CCD camera, thereby calculating correction data.

[0017]

Also in the ball motion measuring apparatus, the shift of the apparent coordinates on the original image from the true coordinates is corrected. Accordingly, the ball motion can be measured with high precision. More specifically, the data obtained from the original image can be converted into data obtained by photographing the front part of the ball at infinity. The correction will be hereinafter referred to as "oblique correction".

[0018]

The process or correction is particularly effective for measurement to be carried out by means of a camera having a horizontal view angle of 10 degrees or more by using a wide-angle lens. As a matter of course, also in the case in which a standard lens or a telephoto lens is used, an enhancement in the precision

can be obtained. The "horizontal view angle of 10 degrees" implies that a photographic range in a horizontal direction is ±5 degrees to a forward direction.

【0019】

【Description of the preferred embodiments】

The present invention will be described below in detail based on a preferred embodiment with reference to the drawings.

【0020】

Fig. 1 is a plane view showing an example of a ball motion measuring apparatus of the present invention. Further, Fig. 2 is a front view of the ball motion measuring apparatus. The present ball motion measuring apparatus serves to measure the motion (a spin rate, a flight speed, a launch angle and the like) of a golf ball. The ball motion measuring apparatus comprises a tee 3 for mounting a golf ball 1 thereon, a first camera 5, a second camera 7, a pair of first stroboscopes 9, a pair of second stroboscopes 11, a pair of optical sensors 13, a CPU 15 to be a calculating section, and a monitor 17 to be a display section. The first camera 5 and the second camera 7 are CCD cameras having a shutter function. The CCD camera comprises a wide-angle lens and has a wide photographic range (a horizontal view angle of 10 degrees or more). Usually, a camera having a horizontal view angle of 150 degrees or less is used. The shutters of the first camera 5 and the second camera 7 are opened or closed by a control section (not shown) receiving a trigger signal which will be described below.

【0021】

When the motion of the golf ball 1 is to be measured by the ball motion measuring apparatus, the golf ball 1 is first mounted on the tee 3 and a golf player 19 swings a golf club 21. Consequently, a head 23 passes through a portion just above the optical sensor 13. A head speed can be calculated from a deviation of the times at which the head 23 passes through the portions just above the two optical sensors 13 and 13. By the passage of the head 23, the trigger signal is generated from the optical sensor 13.

[0022]

Then, the head 23 collides with the golf ball 1. The golf ball 1 is launched in an obliquely upper right direction in Fig. 2. After a predetermined time passes since the optical sensor 13 generates the trigger signal, the shutter of the first camera 5 is opened. Moreover, the first stroboscope 9 emits light synchronously with the opening operation of the shutter. Consequently, an original image is photographed by means of the first camera 5. After a predetermined time further passes since the first camera 5 carries out the photographic operation, the shutter of the second camera 7 is opened. Moreover, the second stroboscope 11 emits light synchronously with the opening operation of the shutter. Consequently, an original image is also photographed by means of the second camera 7. Both of the original images are static images. Data on the respective original images are sent to the CPU 15. The CPU 15 carries out a process which will be described below in detail.

[0023]

The positions of the first camera 5 and the second camera 7 are determined such that the flying golf ball 1 can be photographed. The positions of the cameras 5 and 7 are usually determined such that the golf ball 1 can be photographed in almost the central part of the original image when the golf player 19 having a average head speed swings the average golf club 21. Consequently, the angles of view of the cameras 5 and 7 are increased, and furthermore, the golf ball 1 can be photographed on almost all original images even if the golf player 19 takes turns or the golf club 21 is changed. The ball motion measuring apparatus may be constituted such that a sound sensor for detecting a hitting sound is provided to generate a trigger signal.

[0024]

Fig. 3(a) shows an original image photographed by means of the first camera 5. Since the angle of view of the first camera 5 is great, a ball image 25 is photographed to be small in the original image. Fig. 3(b) shows a magnified image

obtained by carrying out a magnifying process over the original image data. The magnifying process serves to magnify a rectangular portion (a portion including the ball image 25 in the original image) surrounded by a two-dotted chain line in the original image of Fig. 3(a). The monitor 17 displays the magnified image.

[0025]

As shown in Fig. 3(b), a black recognition mark 27 is provided on the surface of the golf ball 1. The operator points the recognition mark 27 on the screen of the monitor 17. An input pen or the like is used for the pointing. By the pointing, a read value is read. Since the ball image 25 is magnified and displayed, a read value error is made during the pointing with difficulty. Similarly, the original image photographed by means of the second camera 7 is also subjected to the magnifying process so that a magnified image is displayed on the monitor 17. Then, the recognition mark 27 is pointed.

[0026]

The rotating angle of the golf ball 1 from the photographing operation of the first camera 5 to that of the second camera 7 is obtained from the read values of two magnified images. The spin rate of the golf ball 1 is calculated from the rotating angle and a time interval from the photographing operation of the first camera 5 to that of the second camera 7. Since the precision in the pointing is high, data on the spin rate thus obtained also have high precision. The launch angle, the flight speed and the like may be measured by the pointing. Also in this case, the data have high precision by the magnifying process.

[0027]

The original image photographed through the lens generates a distortion. In particular, in the case in which a camera having a great angle of view is used, the distortion is high. Fig. 4 shows a sample image 29 obtained by photographing a sample plate having a lattice pattern through the first camera 5. As is apparent from Fig. 4, a square 31

in the vicinity of the center of the sample image 29 has a contour shape close to a quadrate and the shape of a square 33 in a peripheral portion is changed. As a distance from the center of the sample image 29 is increased, the degree of the distortion becomes higher. Apparently, an error is made between apparent coordinates in the original image data and true coordinates when the golf ball 1 is photographed by means of the first camera 5.

[0028]

The coordinates (true coordinates) in the sample plate are grasped in advance. A predetermined point is extracted from the sample image 29 (the image shown in Fig. 4) and is subjected to the pointing so that an error range between the apparent coordinates and the true coordinates can be obtained. Based on the error range, a correction ratio is calculated. The correction ratio is not uniform but is varied depending on the distance from the center of the image. In other words, the correction ratio is more increased in a portion closer to the periphery.

[0029]

Based on the correction ratio, the read value obtained from the original image data is subjected to a distortion correcting process. Consequently, correction data are obtained. Similarly, the read value obtained from the original image data of the second camera 7 is also subjected to the distortion correcting process. Consequently, correction data are obtained. The motion of the golf ball 1 can be measured from the two correction data with high precision.

[0030]

Fig. 5 is a plan view showing a state in which the photographing operation of the first camera 5 is carried out. In Fig. 5, a line f indicates a direction of an optical axis of the first camera 5 and a line s indicates a reference plane. The reference plane is extended in an x-y direction. The lines f and s are orthogonal to each other on a reference point O. A point P indicates a focal point of a lens, a point Q indicates

a position of the recognition mark 27 provided on the surface of the golf ball 1, and a point R indicates a point obtained by projecting the point Q onto the reference plane. The golf ball 1 flies in almost the x direction (a right direction in Fig. 5) slightly upward. In the original image photographed in the state shown in Fig. 5, the direction of the ball image seen from the first camera 5 is shifted from the direction of the optical axis. The ball image is positioned on the right part of the original image.

【0031】

A point T0 is the center of the golf ball 1. When the reference point O is an origin, a true x coordinate of the center T0 is "a". In the original image data, one of ends of the golf ball 1 is regarded as a point T1 and the other point is regarded as a point T2. Accordingly, an intermediate point T3 of the points T1 and T2 is regarded as the apparent center of the golf ball 1. When the reference point O is an origin, an x coordinate of the apparent center of the golf ball 1 is regarded as "a′". More specifically, an error is made between the apparent coordinates in the original image data and the true coordinates (assuming that the front part of the golf ball 1 is photographed at infinity). The true x coordinate of "a" can be calculated by the following equation:

$$a = a' \times (L^2 - r^2) / L^2$$

wherein a distance of a segment PO is represented by L and a radius of the golf ball 1 is represented by r.

【0032】

Since the golf ball 1 is launched obliquely upward, a y coordinate of the center of the golf ball 1 is not zero. A true y coordinate of "b" can be calculated by the following equation:

$$b = b' \times (L^2 - r^2) / L^2$$

wherein an apparent y coordinate in the original image data photographed by means of the first camera 5 is represented by "b′" and an actual y coordinate is represented by "b".

[0033]

Thus, the read values (a′ and b′) obtained by the original image data are converted into the correction data (a and b) obtained by photographing the front part of the ball so that true coordinates (a, b, 0) of the center of the golf ball 1 are determined.

[0034]

A read value obtained from the original image data of the second camera 7 is also subjected to oblique correction. The flight speed, the launch angle and the like of the golf ball 1 are measured with high precision from the correction data of the first camera 5 and the correction data of the second camera 7. In some cases in which the swing track of the golf player 19 is not straight or a misshot is made, the center of the golf ball 1 is shifted from the reference plane. More specifically, a z coordinate of the center of the golf ball 1 is not zero in some cases. In these cases, it is preferable that the correction should be carried out in consideration of a shift in the z direction. A width of the shift in the z direction can be calculated from the size of the ball image in the original image, for example.

[0035]

In the case in which it is assumed that the point R has coordinates of (u′, v′, 0) and the center T0 of the golf ball 1 is positioned on the optical axis f, the position of the point Q is set to be a point Q_0. Moreover, it is assumed that the coordinates of the point Q_0 are (x_0, y_0, z_0) when the center of the golf ball 1 is an origin. Moreover, it is assumed that a length of a segment PQ is set to be "k" times as great as that of a segment PR. The point Q_0 is provided on a spherical surface. Therefore, a relationship expressed by the following equation (I) is established.

$$x_0^2 + y_0^2 + z_0^2 = r^2 \quad \text{--- (I)}$$

Moreover, since the coordinates of the point Q are ($x_0 + a$, $y_0 + b$, z_0), the following equations (II) to (IV) are established.

$$x_0 + a = k \times u' \quad \text{--- (II)}$$

$$y_0 + b = k \times v' \quad \text{--- (III)}$$

$$z_0 - L = -(k \times L) \quad \text{--- (IV)}$$

【0036】

Since the values of "u'" and "v'" are read from the original image data, the value of "k" is calculated based on the equations (I) to (IV). There are two solutions obtained from a quadratic equation for "k". One of the solutions corresponds to a point on this side of the reference plane s (closer to the CCD camera 5) and the other corresponds to an inner point of the reference plane s. A point at which the photographing is to be carried out is provided on this side of the reference plane s. Therefore, one of the two solutions which corresponds to the point on this side is employed to be the value of k. The values of x_0, y_0 and z_0 are determined by the value of k and the equations (II) to (IV). Similarly, the values of x_0, y_0 and z_0 are determined by the original image data obtained through the second camera 7. Based on the correction data, a spin rate can be obtained based on vector calculation. Japanese Patent No. 2810320 has disclosed a method for vector calculation as an example. Since the spin rate is obtained from the correction data after the oblique correction is carried out, precision thereof is high.

【0037】

While the ball motion measuring apparatus has such a structure that a ball image is displayed on the monitor 17 and an operator points a display screen to read a value, the value may be automatically read through an image processing or the like. In case of the automatic reading operation, the monitor

17 may be omitted.

[0038]

While two original images are photographed by means of two cameras in the ball motion measuring apparatus, three or more cameras may be provided. Moreover, the ball motion measuring apparatus may have such a structure that two or more ball images can be photographed on the original image photographed by means of one camera.

[0039]

While the magnifying correction, the distortion correction and the oblique correction can be carried out in the ball motion measuring apparatus, the ball motion measuring apparatus may have such a structure that any one or two of them can be performed.

[0040]

[Experiment 1]

[Experiment Example A]

A CCD camera having a wide-angle lens was prepared for first and second cameras. In the CCD camera, a visual field range in a horizontal direction is 250 mm (a horizontal view angle of 45.24 degrees) when a distance between a focal point P and a reference plane is 300 mm. The positions of both cameras are regulated such that a ball image was photographed in almost the central part of an original image and a golf ball mounted on a tee was hit. The flying golf ball was photographed in a shifted timing by means of two cameras so that two original images were obtained. The original images were displayed on a monitor and a flight speed, a launch angle, a backspin rate and a sidespin rate of the golf ball were calculated through an operation for pointing a recognition mark by an operator. The pointing operation and the calculation were repeated ten times to obtain a variation ($4 \times \sigma$).

[0041]

[Experiment Example B]

Original image data obtained in the experiment example A were subjected to a magnifying process having a double

magnification ratio so that a magnified image was obtained. Based on the magnified image, the same pointing operation and calculation as those in the experiment example A were repeated ten times. Thus, a variation ($4 \times \sigma$) was obtained.

[0042]

[Table 1]

Table 1 Result of Experiment 1

		Experiment Example A	Experiment Example B
Type of lens		Wide angle	Wide angle
Magnifying correction ratio		No	X 2
Distortion correction		No	No
Oblique correction		No	No
Position of ball image in original image	First camera	Center	Center
	Second camera	Center	Center
Variation	Flight speed (m/s)	0.18	0.11
	Launch angle (deg.)	0.31	0.15
	Backspin rate (rpm)	180	88
	Sidespin rate (rpm)	168	84

[0043]

In the Table 1, a measured value has a smaller variation in the experiment example B than that in the experiment example A. Consequently, it is apparent that precision in measurement can be enhanced by the magnifying process.

[0044]

[Experiment 2]

[Experiment Example C]

The same first and second cameras as those in the experiment example A were prepared. The position of the first camera was regulated such that a ball image can be photographed

on the lower left part of an original image and the position of the second camera was regulated such that a ball image can be photographed on the upper right part of the original image. Then, a flying golf ball was photographed by means of the two cameras in a shifted timing. An original image thus obtained was subjected to a double magnifying process. Thus, two magnified images were obtained. The magnified images were displayed on a monitor so that a read value was obtained through an operation for pointing a recognition mark by an operator. A flight speed and a launch angle of the golf ball were calculated from the read value. The pointing operation and the calculation were repeated ten times. Thus, a mean value was obtained.

【0045】

[Experiment Example D]

The read value obtained by the pointing operation according to the experiment example C was subjected to oblique correction so that correction data were obtained. A mean value of each of a flight speed and a launch angle was obtained from the correction data.

【0046】

[Experiment Example E]

The read value obtained by the pointing operation according to the experiment example C was subjected to distortion correction so that correction data were obtained. A mean value of each of a flight speed and a launch angle was obtained from the correction data.

【0047】

[Experiment Example F]

The read value obtained by the pointing operation according to the experiment example C was subjected to oblique correction and distortion correction so that correction data were obtained. A mean value of each of a flight speed and a launch angle was obtained from the correction data.

【0048】

[Reference Example]

A first sensor through which a laser beam passes

vertically was provided in almost the same position as the position of the ball image of a first camera. Moreover, a second sensor through which a laser beam passes vertically was provided in almost the same position as the position of the ball image of a second camera. A time required for the passage of a golf ball from the first sensor to the second sensor was measured to obtain a flight speed. The flight speed approximates to a true value. Moreover, a line sensor through which a laser beam passes horizontally was provided ahead of the ball image of the second camera in the direction of flight. A launch angle was calculated based on a height of the golf ball passing through the line sensor and a height of the golf ball mounted on a tee. The launch angle approximates to a true value.

[0049]

[Table 2]

Table 2 Result of Experiment 2

		Experiment Example C	Experiment Example D	Experiment Example E	Experiment Example F	Ref. Ex. (true value)
Type of lens		Wide angle	Wide angle	Wide angle	Wide angle	Measurement By Laser sensor
Magnifying correction ratio		x 2	x 2	x 2	x 2	
Distortion correction		No	No	Yes	Yes	
Oblique correction		No	Yes	No	Yes	
Position of ball image in original image	First camera	Lower left	Lower left	Lower left	Lower left	
	Second camera	Upper right	Upper right	Upper right	Upper right	
Flight speed(m/s)		56.5	56.3	58.0	57.8	57.8
Launch Angle(deg.)		11.2	11.2	12.1	12.1	12.1

[0050]

From the Table 2, it is apparent that the measured value approximates to a true value by the distortion correction.

【0051】

[Experiment 3]

[Experiment Example G]

An XY table was prepared and provided on a reference plane s. Two golf balls were fixed to the XY table. The positional relationship between the two golf balls (the relationship including a backspin) was set to be almost equivalent to that between two ball images in the case in which photographing was carried out twice in a shifted timing from the trajectory of the hit golf ball. On the other hand, the same first and second cameras as those in the experiment example A were prepared. The position of the first camera was regulated such that one of the golf balls can be photographed on the center of an original image and the position of the second camera was regulated such that the other golf ball can be photographed on the left part of the original image. Then, two original images obtained by the respective cameras were subjected to a magnifying process (double). Thus, two magnified images were obtained. The magnified images were displayed on a monitor so that a read value was obtained through an operation for pointing a recognition mark by an operator. The read value was subjected to distortion correction so that correction data were obtained. A backspin rate and a sidespin rate were calculated from the correction data. The pointing operation and the calculation were repeated ten times. Thus, a mean value was obtained.

【0052】

[Experiment Example H]

A mean value of each of a backspin rate and a sidespin rate was calculated in the same manner as in the experiment example G except that distortion correction and oblique correction were carried out to obtain correction data.

【0053】

[Experiment Example I]

A mean value of each of a backspin rate and a sidespin

rate was calculated in the same manner as in the experiment example G except that the other golf ball was moved without a rotation over an XY table and was photographed on the right part of an original image.

【0054】

[Experiment Example J]

A mean value of each of a backspin rate and a sidespin rate was calculated in the same manner as in the experiment example I except that distortion correction and oblique correction were carried out to obtain correction data.

【0055】

[Experiment Example K]

A CCD camera having a telephoto lens was prepared for first and second cameras. The telephoto lens has a visual field range of 60 mm with a distance between a focal point P and a reference plane of 2300 mm. A golf ball put on an XY table was moved without a rotation and a position was regulated such that a ball image can be photographed on almost the center of an original image. Two original images obtained by the respective cameras were not subjected to correction but displayed on a monitor. The ball images thus displayed were sufficiently large. A backspin rate and a sidespin rate were calculated through an operation for pointing a recognition mark by an operator. The pointing operation and the calculation were repeated ten times so that a mean value was obtained. The backspin rate and sidespin rate thus obtained approximate to true values.

【0056】

【Table 3】

Table 3 Result of Experiment 3

		Experiment Example G	Experiment Example H	Experiment Example I	Experiment Example J	Experiment Example K
Type of lens		Wide angle	Wide angle	Wide angle	Wide angle	Telephoto
Magnifying correction ratio		x 2	x 2	x 2	x 2	No
Distortion correction		Yes	Yes	Yes	Yes	No
Oblique correction		No	Yes	No	Yes	No
Position of ball image in original image	First camera	Center	Center	Center	Center	Center
	Second camera	Left	Left	Right	Right	Center
Backspin rate (rpm)		2183	2410	3243	2399	2420
Sidespin rate (rpm)		781	103	-2323	126	140

【0057】

From the Table 3, it is apparent that the measured value approximates to a true value through oblique correction also in the case in which the wide-angle lens is used.

【0058】

While the ball motion measuring apparatus according to the present invention has been described by taking the golf ball as an example, the present invention can be used for measuring all balls such as a tennis ball.

【0059】

【Effect of the invention】

As described above, an apparatus for measuring the motion of a ball may present a measurement with high precision.

【Brief description of the drawings】

【FIG 1】

Fig. 1 is a plan view showing a ball motion measuring apparatus according to an embodiment of the present invention,

【FIG 2】

Fig. 2 is a front view showing the ball motion measuring apparatus in Fig. 1,

【FIG 3】

Fig. 3(a) is a front view showing an original image,

Fig. 3(b) is a front view showing a corrected image,

【FIG 4】

Fig. 4 is a view showing a sample image in which a sample plate having a lattice pattern is photographed, and

【FIG 5】

Fig. 5 is a plan view showing the state of photographing carried out by means of a first camera.

【Explanation of reference numerals】

1…golf ball

5…first camera

7…second camera

9…first stroboscope

11…second stroboscope

13…optical sensor

15…CPU

17…monitor

25…ball image

27…recognition mark

【Name of document】 Drawings

【FIG 1】

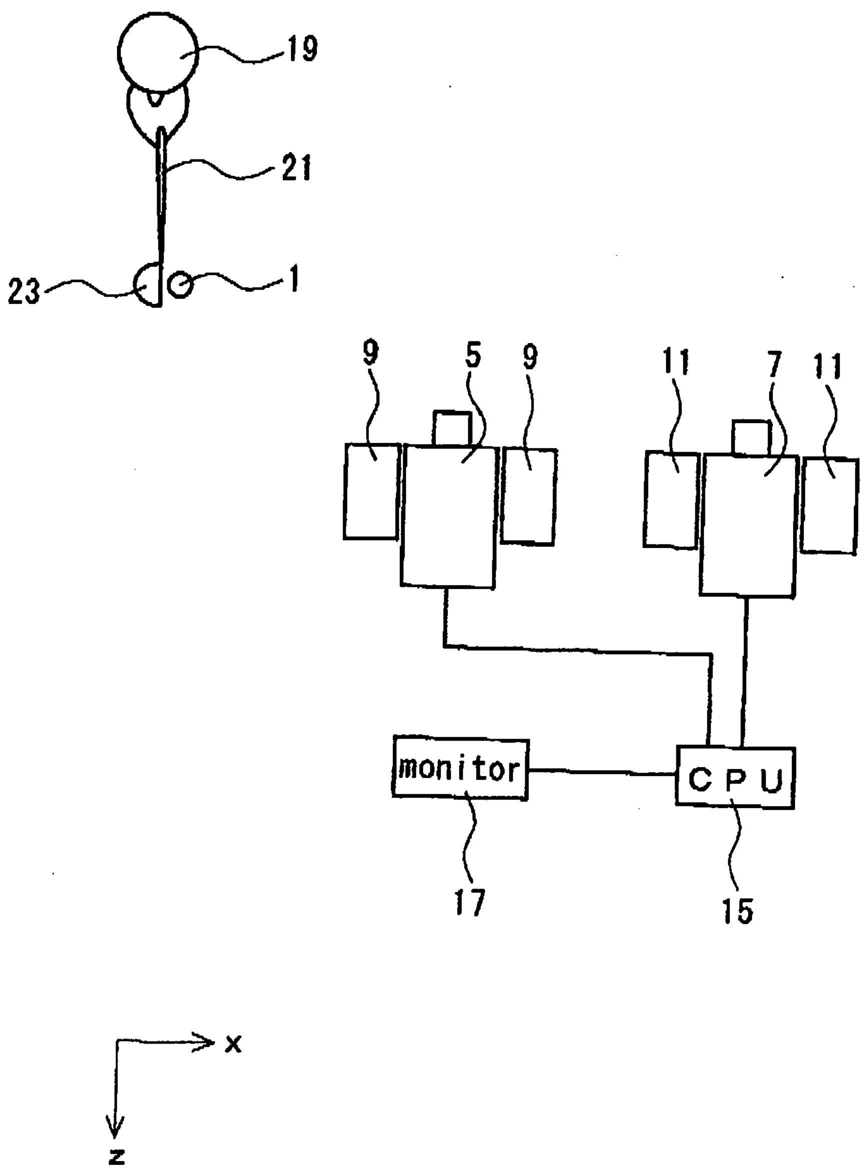

Fig. 1

【FIG 2】

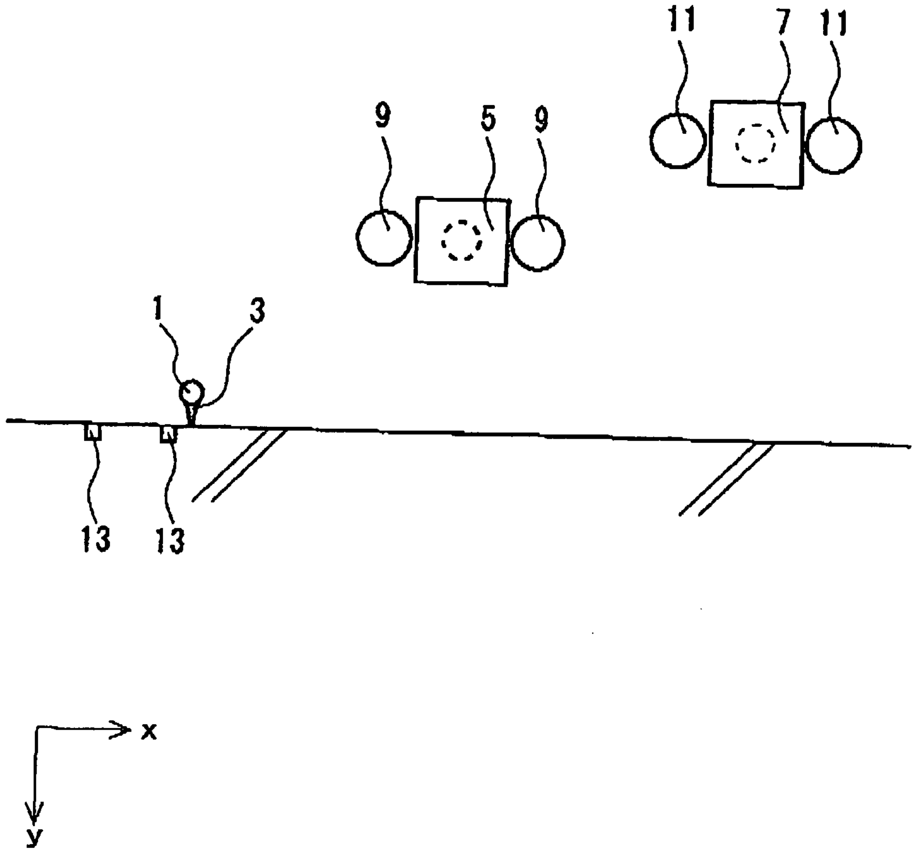

Fig. 2

【FIG 3】

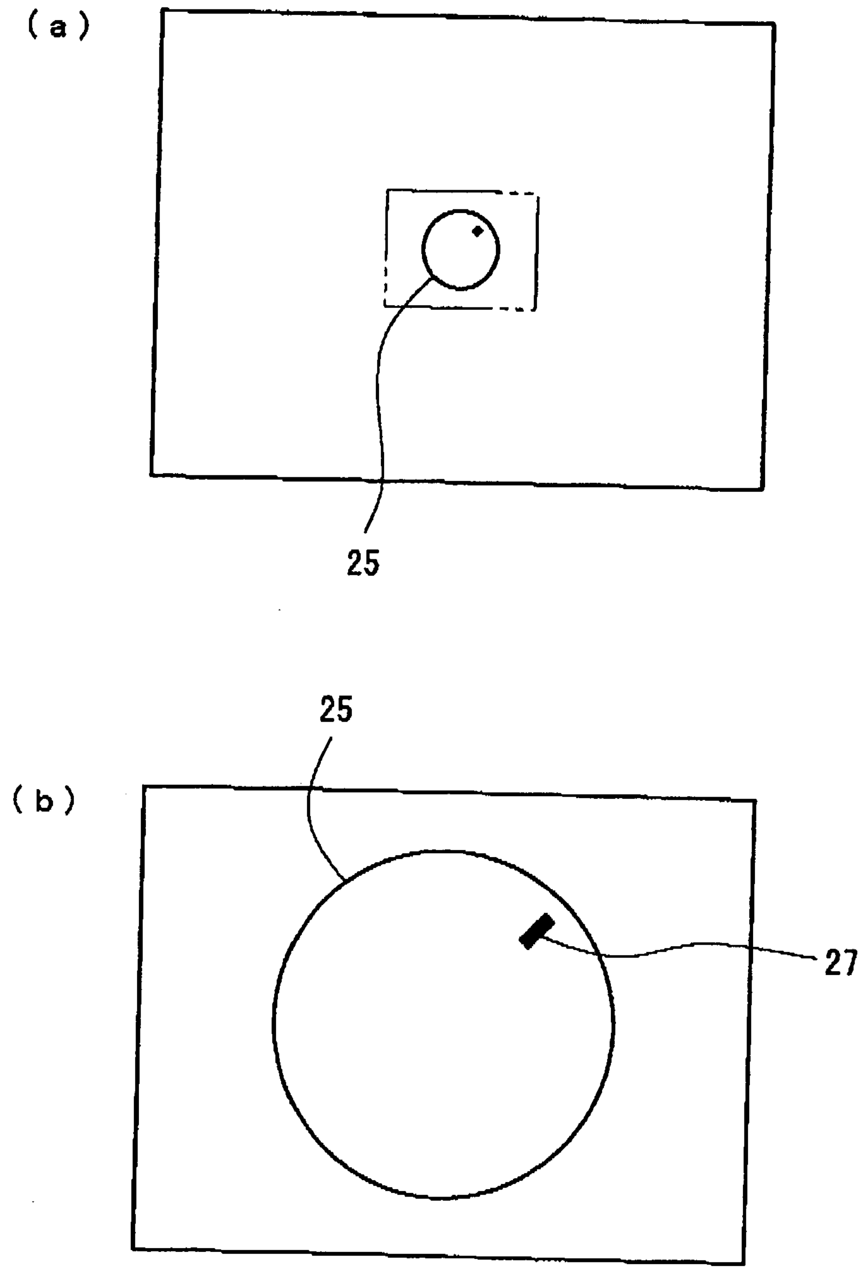

Fig. 3

【FIG 4】

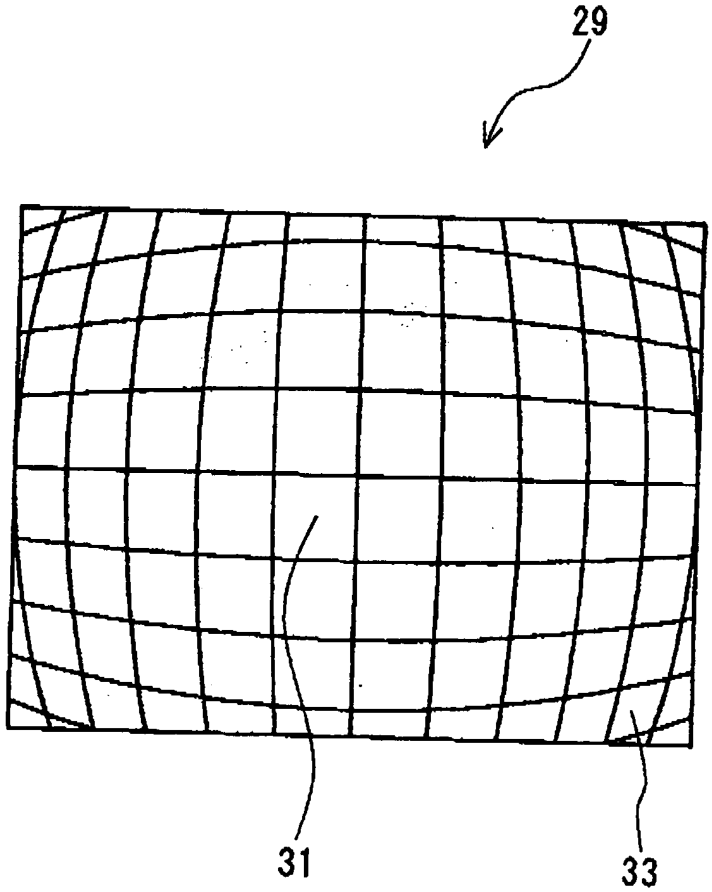

Fig. 4

【FIG 5】

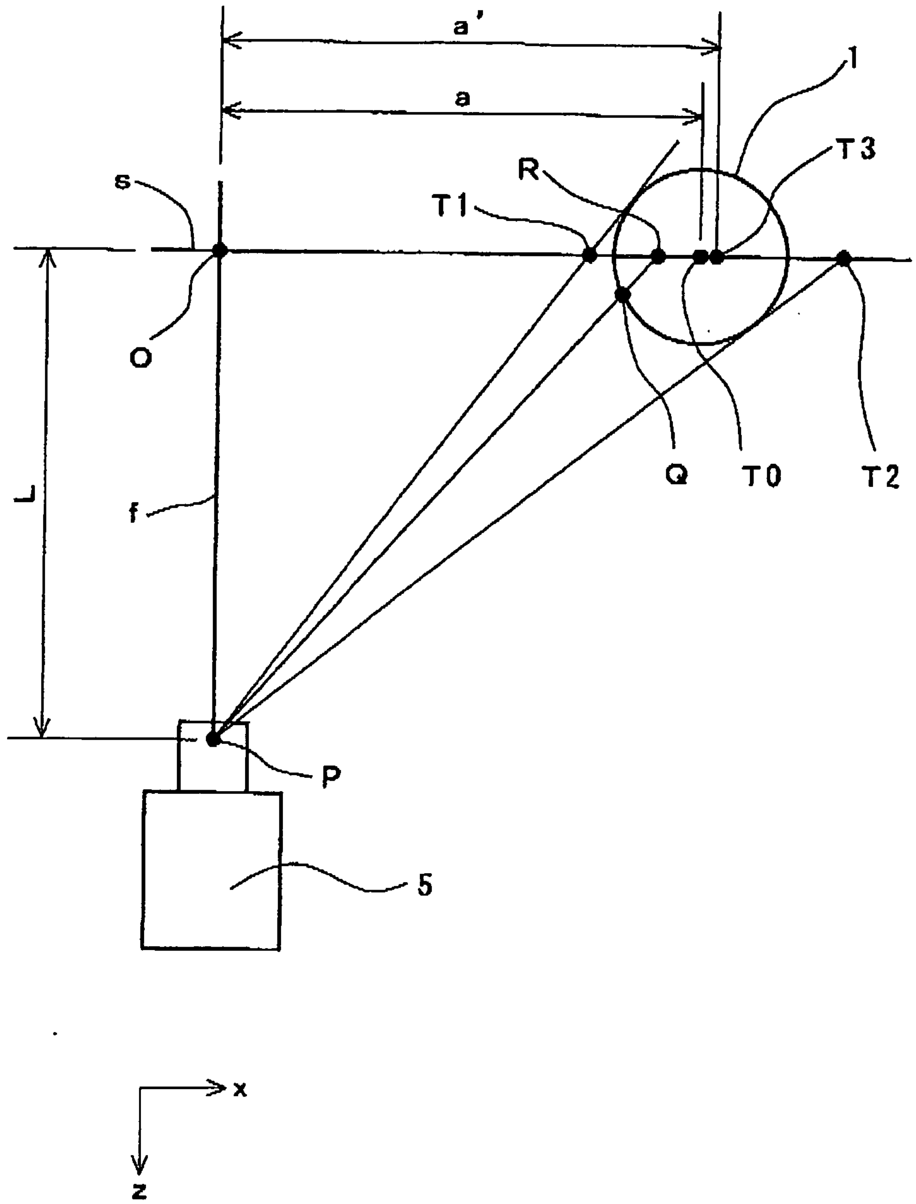

Fig. 5

【Name of the document】 Abstract

【Abstract】

【Problem to be solved】

The present invention is aimed to provide an apparatus for measuring the motion of a ball with high precision.

【Method for solving the problem】

A ball motion measuring apparatus comprises a tee 3 for mounting a golf ball 1 thereon, a first camera 5, a second camera 7, a pair of first stroboscopes 9, a pair of second stroboscopes 11, a pair of optical sensors 13, a CPU 15 to be a calculating section, and a monitor 17 to be a display section. The first camera 5 and the second camera 7 are CCD cameras having a shutter function. Photographing is carried out by means of the first camera 5 after a predetermined time passes since the golf ball 1 is hit, and the photographing is carried out by means of the second camera 7 after a predetermined time further passes. A magnified image is formed by original image data thus obtained and a read value obtained by pointing the magnified image is subjected to distortion correction or oblique correction so that correction data are obtained. Based on the correction data, a flight speed, a spin rate or a launch angle of the golf ball 1 is calculated.

【Selected Drawing】 FIG 1

Information as to the applicant

Identification Number [000183233]

1. Date of changing the record: August 17, 1994
[Reason of changing the record] Address change
Address: 6-9, 3-Chome, Wakinohama-cho, Chuo-ku, Kobe-shi, Hyogo
Name: SUMITOMO RUBBER INDUSTRIES, LTD.

Provisional Application For Patent Cover Sheet

Address to:
Assistant Commissioner for Patents
Box Provisional Application
Washington, DC 20231
This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. § 1.53(c).

Docket Number: 36719:167380	Type a plus sign (+) inside this box ☞	+

INVENTOR(S)/APPLICANT(S)

Last Name	First Name	Middle Initial	Residence (City and either State or Foreign Country)
1) EDELSON	Steven	D.	Wayland, MA 01778-2101
2) DIEPOLD	Klaus	-	Siegertsbrunn, GERMANY

TITLE OF THE INVENTION (280 Characters Maximum)

Surveillance Video Enhancement

CORRESPONDENCE ADDRESS (including country if not United States)

VENABLE
P. O. BOX 34385

State: Washington, DC Zip Code: 20045-9998 Country: US

ENCLOSED APPLICATION PARTS (*check all that apply*)

☒ Specification *Number of pages*: 13 ☒ Small Entity Statement
☒ Drawing(s) *Number of sheets*: 1 ☐ Other (specify) ____________

Method Of Payment (*check one*)

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☒	Our check is enclosed to cover the Provisional filing fees.	
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No
☐ Yes, the name of the U.S. Government agency and the Government contract number are: ____________

Respectfully submitted,

Signature: Richard L. Aitken Date: Nov 6, 2000
Typed or Printed Name: Richard L. Aitken Registration No. 18,791
(*if appropriate*)

☐ Additional inventors are being named on separately numbered sheets attached hereto.

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

013 APP
SKGF Rev 12/1/97mac

Applicant or Patentee: Steven D. Edelson et al
Application or Patent No.: To be assigned
Filed or Issued: Herewith
For: SURVEILLANCE VIDEO ENHANCEMENT

Attorney Docket: 36719:167380

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 CFR 1.9(f) and 1.27(c)) - SMALL BUSINESS CONCERN

I hereby declare that I am
[ ] the owner of the small business concern identified below;
[ ] an official of the small business concern empowered to act on behalf of the concern identified below:
NAME OF CONCERN: DYNAPEL SYSTEMS, INC.

ADDRESS OF CONCERN: 380 Lexington Avenue, Suite 4500, New York, New York 10168-1495

I hereby declare that the above-identified small business concern qualifies as a small business concern as defined in 12 C.F.R. §§ 121.3-18, and reproduced in 37 C.F.R. § 1.9(d), for purposes of paying reduced fees under sections 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the fiscal year of the concern of the persons employed on a full-time, part-time, or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other, either directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled SURVEILLANCE VIDEO ENHANCEMENT inventor(s) Steven D. Edelson and Klaus Diepold described in

[x] the specification filed herewith
[ ] Application filed
[ ] Patent No.______________, issued ____________________

If the rights held by the above-identified small business concern are not exclusive, each individual, concern, or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 C.F.R. § 1.9(c) or by any concern which would not qualify as a small business concern under 37 C.F.R. § 1.9(d) or a nonprofit organization under 37 C.F.R. § 1.9(e). *NOTE: Separate verified statements are required from each named person, concern, or organization having rights to the invention averring to their status as small entities. 37 C.F.R. § 1.27.

NAME______________________________
ADDRESS______________________________
[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. 37 C.F.R. § 1.28(b).

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

SIGNATURE Richard L. Aitken DATE Nov 6, 2000

NAME OF PERSON SIGNING: Richard L. Aitken, Registration No. 18,791
TITLE OF PERSON OTHER THAN OWNER: Attorney for DynaPel Systems, Inc.
ADDRESS OF PERSON SIGNING: 1201 New York Avenue, N.W. Washington, D.C. 20005

Surveillance Video Enhancement

Motion - It's something we experience all day every day, we see it, sometimes we hear it and sometimes we hear it and sometimes we, in various ways, feel the effects of it. We use video recordings to store or remotely display such visual experiences. Yet, isn't it strange that, until now, no one treated video as a collection of captured motions? It sounds simple, in theory, but in practice, identifying the motion within a video is very difficult to do.

A Video is composed of a sequence of consecutive pictures, called Frames, photographed in motion by a specially designed camera and shown on display in such a rapid succession as to give the illusion of natural movement of objects, background, and camera perspective.

When a Digital Video is created, the individual Frames of the video are digitized by creating a grid of color dots that represent the frame. The individual dots of color are called Pixels.

A unique way of looking at digital video has been developed. Simply stated, digital video is seen as a collection of motions. There are really two types of motion within a video:

1. Object Motion - such as a person in the foreground or a vehicle in the background.

2. Camera Motion - Panning and/or Zooming to change the perspective of the electronic eye capturing the video.

A new technology employed in this invention is applied at the individual pixel level to identify the motion within a video. The technology can differentiate between the motion of each individual object within the video as well as motion resulting from movement of the camera. The ability to first separate the types of motion and then manipulate the size or position of an object, its direction, velocity and acceleration or the impact of the cameras movement enables an amazing set of applications and capabilities.

Application to Security

Clearly, the single most import feature associated with video surveillance is detecting motion. Often, a security staff is confronted with multiple, simultaneous video streams. Each has its own set of motions; each must be watched at all times. Current offerings may provide a warning when motion occurs, but this is really basic analysis of the video. With the new technology, a vast array of analysis can be performed on the incoming video and the actual display of the video can be modified to highlight important motion and eliminate operator overload.

The following pages will illustrate unique motion technologies using examples common to video surveillance. The motion-based enhancements are grouped into three categories:

1. **Converting Panning Cameras to Stable Panoramic Display**: The hypnotic movement of a panning camera can be transformed into a stable panoramic view of the entire scene. This reduces operator fatigue and keeps everything on-screen - even when the camera has moved to another position.

2. **Making Use of Object Motion**: With motion identified, moving objects can be highlighted, enlarged, tracked and alarmed. More advanced techniques can even tell normal motion from unusual motion.

3. **Compressing Video for Remote Surveillance and archiving**: Motion techniques can greatly increase the compression of video to allow transmission over remote modems as well as shrinking the storage required for archiving video.

Image Stabilization

A non-hardened camera platform can result in small random movements in the video that often make details difficult to distinguish. An Anti-Shake™ technology determines the random camera movement and eliminates it, resulting in smooth, easy to view motion.

Pan & Zoom Governor

In a stressful moment, an operator may move a camera too quickly to accurately view the video. With a technology employed in the invention, frames can be inserted between the

existing frames of video to enable viewing of these events. The pan and zoom governor is described in a copending application entitled A Method and Apparatus for Automatically Adjusting Video Panning and Zoom Rates, filed September 27, 2000 invented by Steven Edelson and Ralph Carballal. This application is hereby incorporated by reference.

Panoramic Display of Sweeping Camera

One type of surveillance camera installation involves having the camera sweep back and forth through a viewing field. This opens holes in security, as problems become "invisible" when the camera is facing away. The present invention can be applied to enable a constant panoramic view of the camera's sweep field to eliminate this problem. In fact, the monitor will always show the entire sweep of the camera as a static display that is constantly updated. Fig. 1 illustrates how such a display screen may appear.

Objects within a video are composed of pixels. The technology for analyzing video and determining a vector defining direction and velocity, for each pixel in a frame of video is disclosed in copending application serial no. 09/593,521 entitled System for the Estimation of Optical Flow, filed June 14, 2000, invented by Siegfried Wonneberger, Max Griessl, and Markus Wittkop. This application is hereby incorporated by reference.

The set of vectors representing the pixel motion from frame to frame is called a dense motion vector field. By analyzing these vectors, we can identify and manipulate individual moving objects within the video.

Currently, cameras pan back and forth slowly so the operator can see a relatively stable scene. By using the panoramic view, the scene is always stable for the operator and the camera speed can be increased to give more rapid updates. Also, because the operator can see the entire viewing area of the camera's pan, there may be a time when he/she wants to get a clear update on a specific object. Rather than wait for the panning camera, a new implementation could allow the camera to snap to that view for real time display.

When the camera is being panned, all of the background pixels will move at substantially the same velocity. As a result, dense motion vector fields can be used to determine the motion component due to camera motion simply by processing the dense motion field vector to determine the most commonly occurring vector, which will correspond to the camera motion component. This camera motion vector, which represents the motion of the camera that is distinct from the motion of objects, is used to determine location of each successive video frame in a panoramic display, each frame being displaced from the previous one by the camera motion vector. Assuming that the camera motion is horizontal panning, the successive frame will be located in an overlapping relationship distributed horizontally across the screen. Each new frame will overwrite the overlapped portion of the preceding frame on the panoramic display so that a vertical strip of the preceding frame remain displayed adjacent to edge of each new frame.

Making Use of Object Motion

Enhancing the Display of Moving Objects

Motion detection, as an enhancement to video surveillance systems is nothing new. However, the motion-based approach of this invention not only enhances this capability, but also enables the user to change the way that moving objects are displayed on the video.

To analyze actual object motion not caused by camera motion, the camera motion vector is subtracted from each vector of the dense motion vector field. This calculation results in a dense motion vector field representing only actual motion of objects, that is object motion net of camera motion.

To identify a moving object, the dense motion vector field net of camera motion is analyzed to find a set of adjacent motion vectors which are the same or similar. The pixels for such vectors will be the pixels of a moving object. An object motion vector representing the motion of the object can then be determined as a vector corresponding to the most commonly occurring vector in the set.

Using object identification and motion estimation techniques, objects in the viewing field can be moved to approximate their location based on their last viewed object motion vector. When an object is again in the view of the camera, its position is updated.

Depending on settable movement limits, a variety of enhancements can be applied to highlight the movement to the operator.

- **Highlight** - Increase the brightness and contrast allowing moving objects to stand out against the background.

- **Color** - Any color can be mixed to color the moving objects. Also, a colored object can have its saturation boosted or lowered to contrast with the background.

- **Haloing** - A bright halo in white or any color can be projected around the moving object.

- **Binocular Effect** - An area surrounding the object can be defined to be magnified. This area will have a zoom effect, magnifying the area by 2x or 4x while leaving the area outside the area unchanged.

- **Background Effects**: In addition to enhancing objects in the display, the background can be modified to further differentiate the moving objects. This can include converting a color background to black & white or applying a defocus filter to the background.

The technology in detecting depicted moving objects and changing the display characteristics of the moving objects is disclosed in a copending application entitled Special Effects in Video in Response to Depicted Motion, filed September 11, 2000, invented by Steven D. Edelson. This application is hereby incorporated by reference. In addition to highlighting a moving object, it is particularly useful in surveillance applications to highlight an object, which was moving, but which is no longer moving.

Suspect & Expected Motion:

Current motion detection systems have no ability to accurately differentiate between suspect and expected motion. They use defined zones that are ignored to deal with areas that will experience regular, expected motion. This inherently leaves a security hole where suspect motion can occur.

With the present invention, the operator can identify the motion of objects that is expected. These objects might be displayed with a blue hue. Should an unexpected motion occur in this area, it would still be flagged, for instance by haloing the object in red, for operator attention. Thus, the area is still under enhanced surveillance. Additionally, using object size and motion information, a system might be produced to enhance rejection of trivial movement such as that of a small animal.

To distinguish expected motion from unexpected or suspect motion, the dense motion vector field representing the expected motion is inputted and stored. This can be done by taking a video of the expected motion, which might be of a rotating fan or rotating rotisserie and storing the dense motion vector field representing the expected motion. The surveillance video dense motion vector fields are then compared with the motion vector field representing the expected motion. Any motion vectors, which do not correspond to the motion vectors of the expected motion, represents unexpected motion or suspect motion and the moving objects corresponding to the unexpected motion is highlighted as suspect motion.

The degree of dissimilarity with the expected motion required for the moving object to be tagged as suspect motion can be varied depending upon the type of expected motion. If the expected motion in constant and unvarying as in a rotating fan, then any substantial variation from the expected motion is tagged and depicted as suspect. If the expected motion is more varied as people walking along a path or a punch press operation, the fields of vectors representing the expected motion and representing the motion question are analyzed and compared to see if two motions are generally the same. If not the motion is tagged as unexpected motion.

High Resolution Visual Bubble:

A motion-isolating technology provides an ability to identify a key area of a video that benefits from high-resolution viewing. (See Figure 2). On detecting motion, the system can be set to automatically define a high resolution "Viewing Bubble" around the suspect motions. If desired, the operator can be given the ability to electronically steer this bubble around the scene to more clearly view items of interest.

Crop & Zoom

Another technology allows cropping of a video in an area of interest generally followed by a zoom to expand the area to full screen. The zoom can also be applied to any section of the video.

Slow Motion Effect

Applying frame interpolation to a full 30fps video to create more frames between existing frames results in a synthetic slow motion effect. This is great for catching motion that is difficult to see at full speed.

The technique of providing slow motion is disclosed in copending application Serial No. 9/459, 987 filed December 14, 1999 entitled Slow Motion System. This application is hereby incorporated by reference.

Anticipating Object Motion

An object in a digital video is a collection of pixels, each of which is assigned a vector defining direction and velocity. By analyzing the vectors of an object's pixels, a motion vector for the object can be determined as described above. With this vector, software can make estimation of the probable location of the object in the near future.

Display of Anticipated Object Motion:

The invention provides the ability to anticipate the movement of an identified object within the video. This can be utilized in at least three ways. First, the display can have an arrow added to the object to indicate the direction and velocity as shown in the Fig. 3. In this example, the subject pushing a cart is moving at 2.6 feet per second at a heading of 045°. Second, the algorithms can estimate a probable location for the object at some time in the future based on its

current motion. This location could be communicated with a graphic object on the display as well. Finally, a number of statistics for the object can be gathered such as time in the display, time from operator flagging until the object leaves display, etc.

Automatically Panning a Camera to Follow Movement:

Once an object has been identified and flagged, it is possible to make use of the object motion vector to move the camera and keep the object centered. This technology could include the ability to anticipate the probable future location of the object and move the camera to that location.

Video Data Reduction And Frame Interpolation

In a copending application Serial No. 09/459, 988 filed December 14, 1999 entitled Motion Picture Enhancing System, a technology is disclosed for generating frames to be interpolated between adjacent frames of a video which is at a slow frame rate to eliminate the jerkiness in the video display. This application is hereby incorporated by reference. The interpolating process of this application is called MediaMend™. In a copending application filed July 17, 2000 entitled Method and Apparatus for Reducing Video Data, invented by Steven D. Edelson, there is disclosed a system for scoring the video frames to determine which frames can be recreated most accurately by the MediaMend™ process, and then eliminating those frames to reduce the video data. This application is hereby incorporated by reference.

Compression for Transmission of a Remote Surveillance Camera to Base Facility

The Problem:

Many companies are using surveillance cameras to observe remote locations as an alternative to expense of basing a human at the location or sending someone out when there is an apparent problem. The surveillance video is commonly transmitted over a telephone line via modem or over the Internet.

Both the telephone and the Internet share a common problem when transmitting video-a distinct lack of bandwidth. The limited available bandwidth does not allow full-size, full-speed video to be transmitted. As a result, current products use compression routines to shrink the size of video prior to transmission.

Unfortunately, most video compression routines for phone or the Internet begin by shrinking the video by simply removing up to 80% of the existing frames. As a result video sent over the Internet or by phone is very jerky. This jerkiness makes interpreting the content of an important surveillance video difficult and error-prone.

The Solution:

A security video transmission system based on the invention can significantly reduce bandwidth utilization and differentiate itself with two significant improvements over current solutions:

1. When the video's background is static, the technology permits sending only the objects that are moving, not the background. The dense motion vector fields net of camera motion are used to identify the moving objects. The stationary background is transmitted only infrequently relative to the moving objects. Bandwidth is saved because the moving objects occupy much less of the scene than the stationary background and therefore the moving objects are represented by much less data. Small objects separated from the background for transmission are called sprites. In accordance with the invention, the sprites may be automatically magnified before or when they are superimposed on the background.

2. Rather than randomly eliminated frames on the camera side, the technology can analyze the video and discard the frames that can be recreated most accurately by MediaMend™ during playback on the receiving computer as described in the above mentioned copending application, Apparatus For Reducing Video Data, filed July 17, 2000. These techniques actually create a video that is smoother (full 30fps), clearer, and smaller than existing systems.

Time Lapsed Storage and Archiving:

The technology of the invention enables a higher level of storage efficiency. The storage of only moving areas can exponentially shrink storage needs. The dense motion vector fields identify the moving areas and then only these identified moving areas are stored. The ability to re-insert frames removed for compression, using MediaMend™ can greatly improve the playback viewing.

FIG 1

Stable View from a Scanning Camera: Note the radar-like highlighted area. This indicates the current view of the camera. As the camera moves, the view area is constantly updated. For a larger image, the scene can be split between two or more monitors.

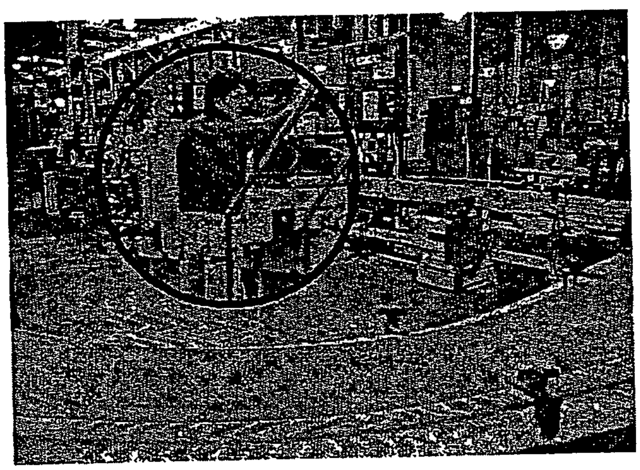

FIG 2

FIG 3